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Title: OPHTHALMOLOGIC APPARATUS
Inventor(s): Toshifumi MIHASHI et al.
DOCKET NO.: 059277-0120

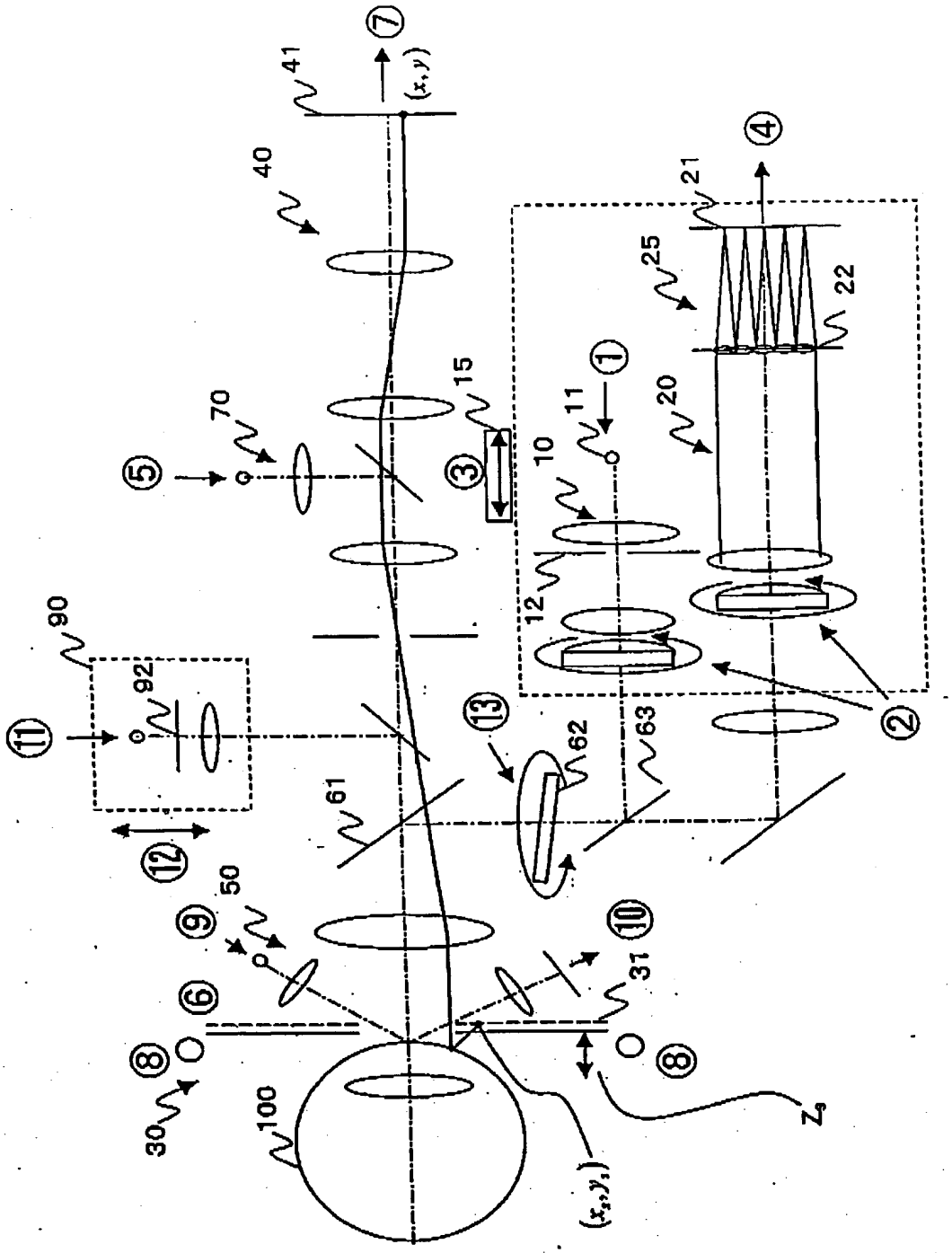

FIG. 1

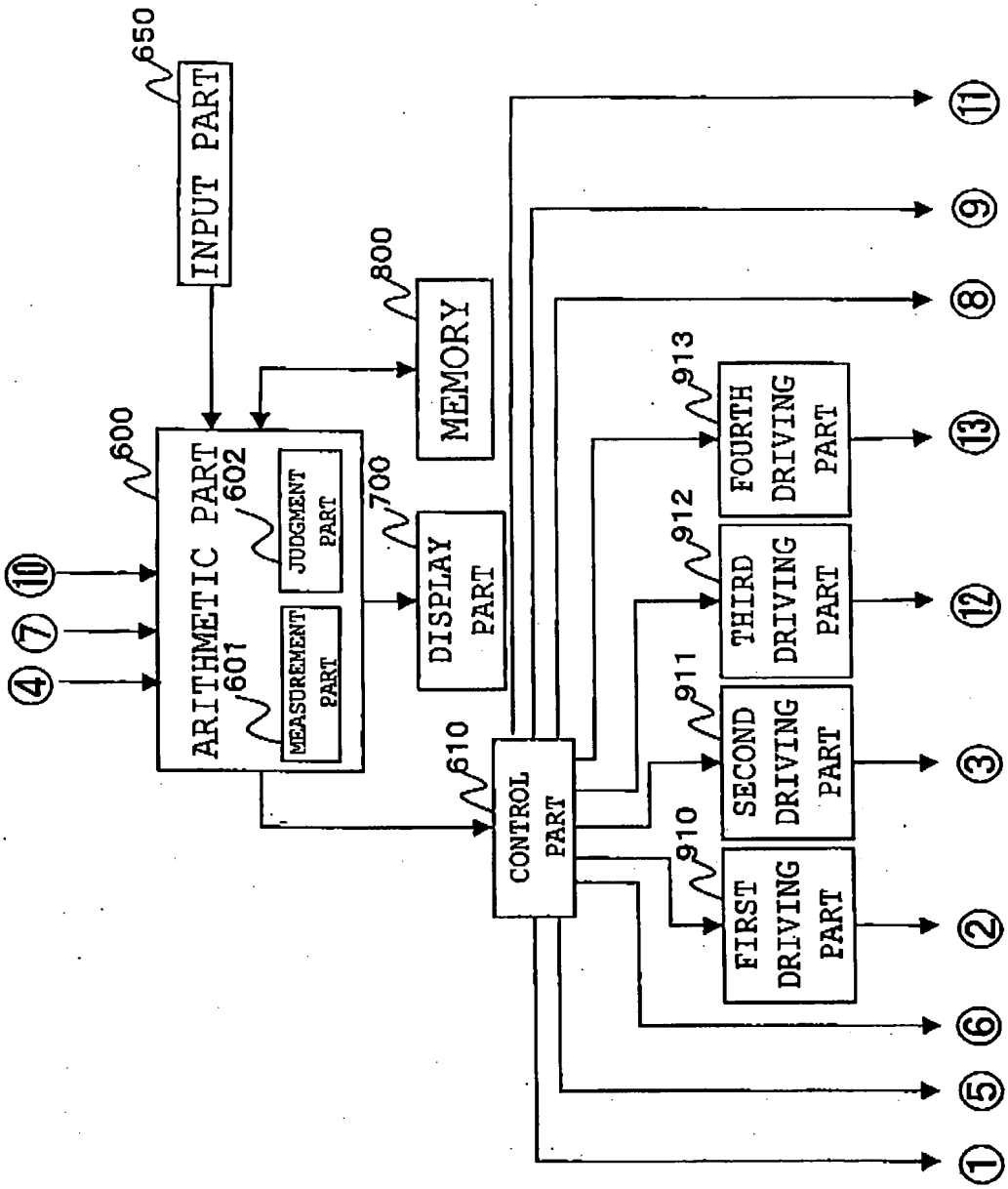
650
INPUT PART
800
MEMORY
600
ARITHMETIC PART
602
JUDGMENT PART
601
MEASUREMENT PART
700
DISPLAY PART
610
CONTROL PART
913
FOURTH DRIVING PART
912
THIRD DRIVING PART
911
SECOND DRIVING PART
910
FIRST DRIVING PART
10
7
4
11
9
8
13
12
3
2
6
5
1

FIG. 2

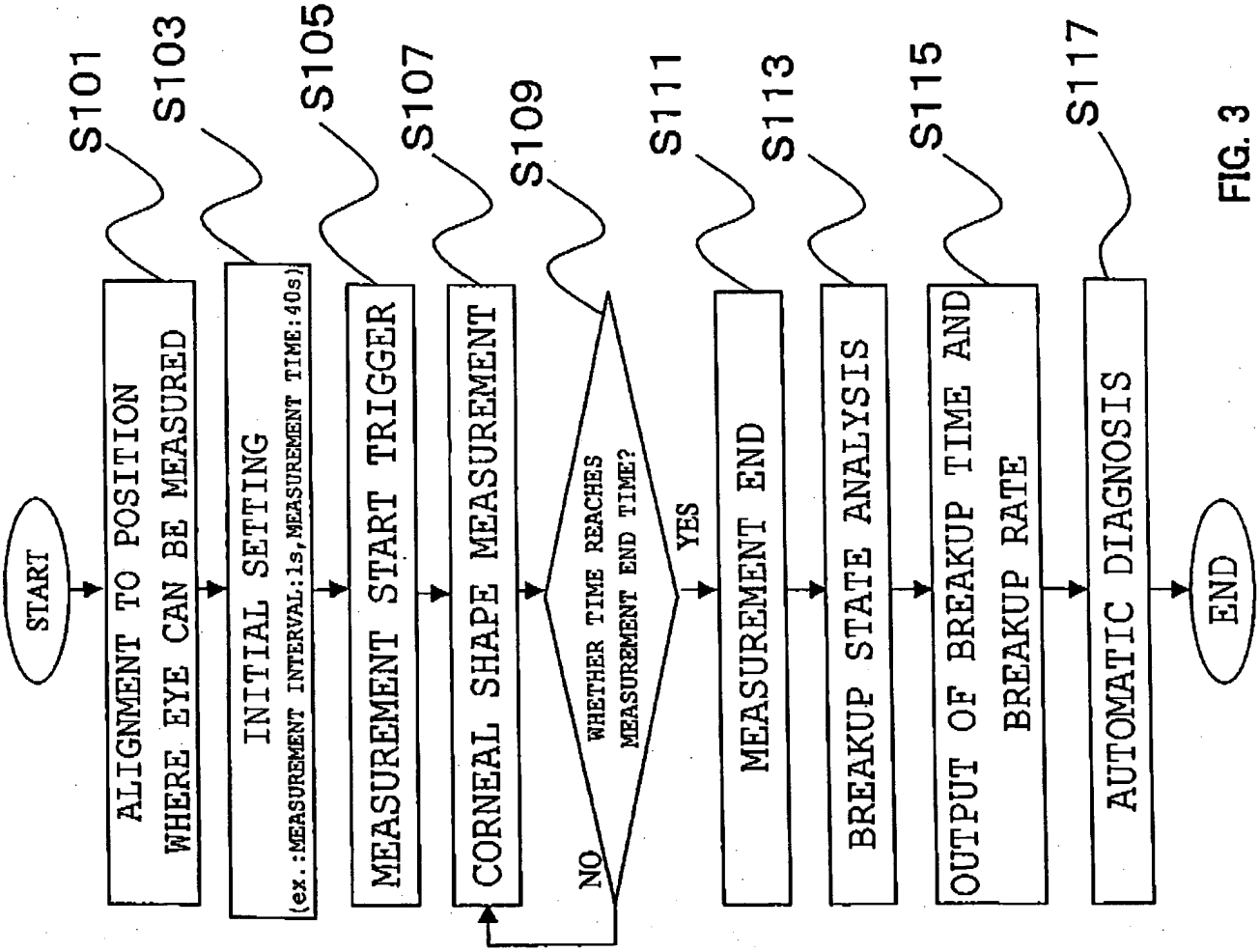
START
S101
ALIGNMENT TO POSITION WHERE EYE CAN BE MEASURED
S103
INITIAL SETTING
(ex.:MEASUREMENT INTERVAL:1s,MEASUREMENT TIME:40s)
S105
MEASUREMENT START TRIGGER
S107
CORNEAL SHAPE MEASUREMENT
S109
WHETHER TIME REACHES MEASUREMENT END TIME?
NO
YES
S111
MEASUREMENT END
S113
BREAKUP STATE ANALYSIS
S115
OUTPUT OF BREAKUP TIME AND BREAKUP RATE
S117
AUTOMATIC DIAGNOSIS
END

FIG. 3

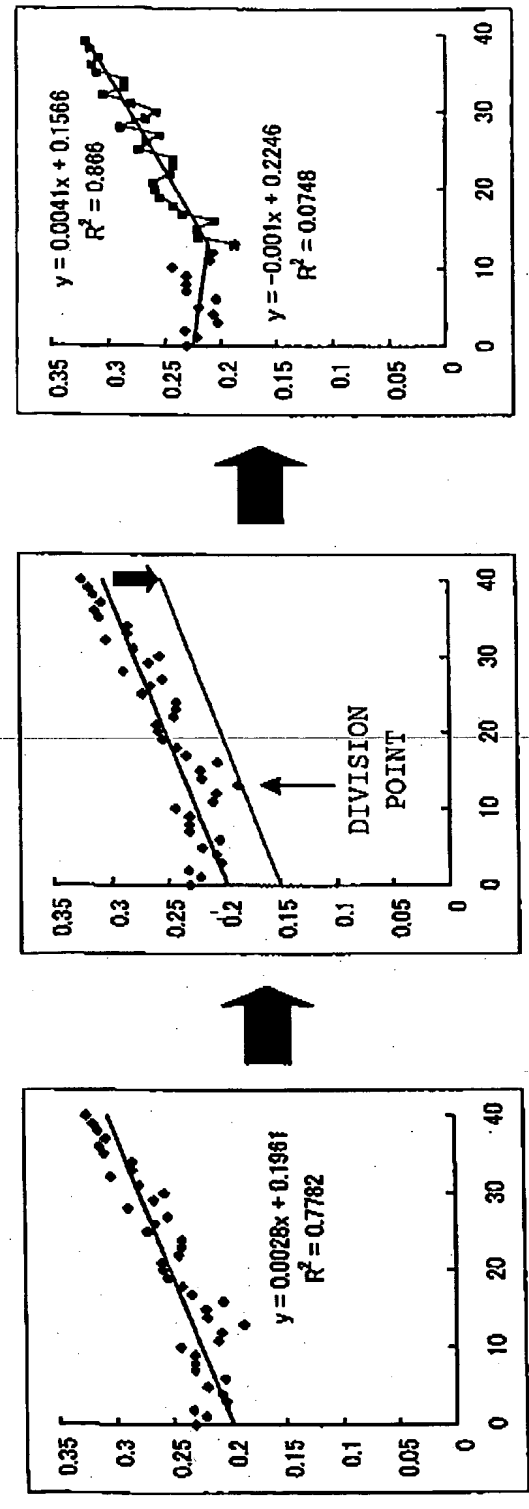
y = 0.0028x + 0.1961
R² = 0.7782
DIVISION POINT
y = 0.0041x + 0.1566
R² = 0.866
y = -0.001x + 0.2246
R² = 0.0748
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40

FIG. 4

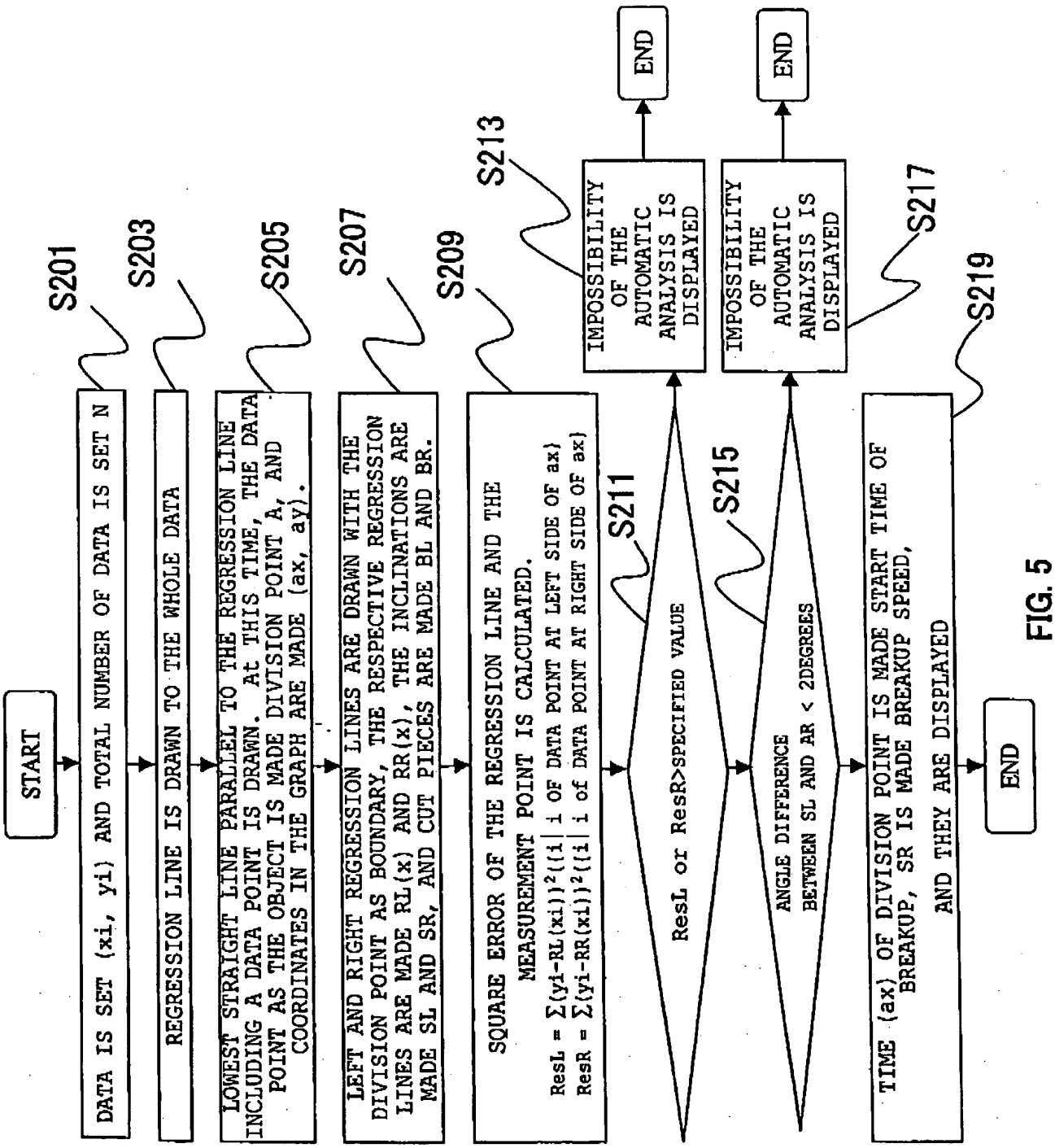
START
S201
DATA IS SET (xi, yi) AND TOTAL NUMBER OF DATA IS SET N
S203
REGRESSION LINE IS DRAWN TO THE WHOLE DATA
S205
LOWEST STRAIGHT LINE PARALLEL TO THE REGRESSION LINE INCLUDING A DATA POINT IS DRAWN. At THIS TIME, THE DATA POINT AS THE OBJECT IS MADE DIVISION POINT A, AND COORDINATES IN THE GRAPH ARE MADE (ax, ay).
S207
LEFT AND RIGHT REGRESSION LINES ARE DRAWN WITH THE DIVISION POINT AS BOUNDARY, THE RESPECTIVE REGRESSION LINES ARE MADE RL(x) AND RR(x), THE INCLINATIONS ARE MADE SL AND SR, AND CUT PIECES ARE MADE BL AND BR.
S209
SQUARE ERROR OF THE REGRESSION LINE AND THE MEASUREMENT POINT IS CALCULATED.
ResL = Σ(yi-RL(xi))²(|i| i OF DATA POINT AT LEFT SIDE OF ax)
ResR = Σ(yi-RR(xi))²(|i| i of DATA POINT AT RIGHT SIDE OF ax)
S211
ResL or ResR>SPECIFIED VALUE
S213
IMPOSSIBILITY OF THE AUTOMATIC ANALYSIS IS DISPLAYED
END
S215
ANGLE DIFFERENCE BETWEEN SL AND AR < 2DEGREES
IMPOSSIBILITY OF THE AUTOMATIC ANALYSIS IS DISPLAYED
END
S217
TIME (ax) OF DIVISION POINT IS MADE START TIME OF BREAKUP, SR IS MADE BREAKUP SPEED,
AND THEY ARE DISPLAYED
S219
END

FIG. 5

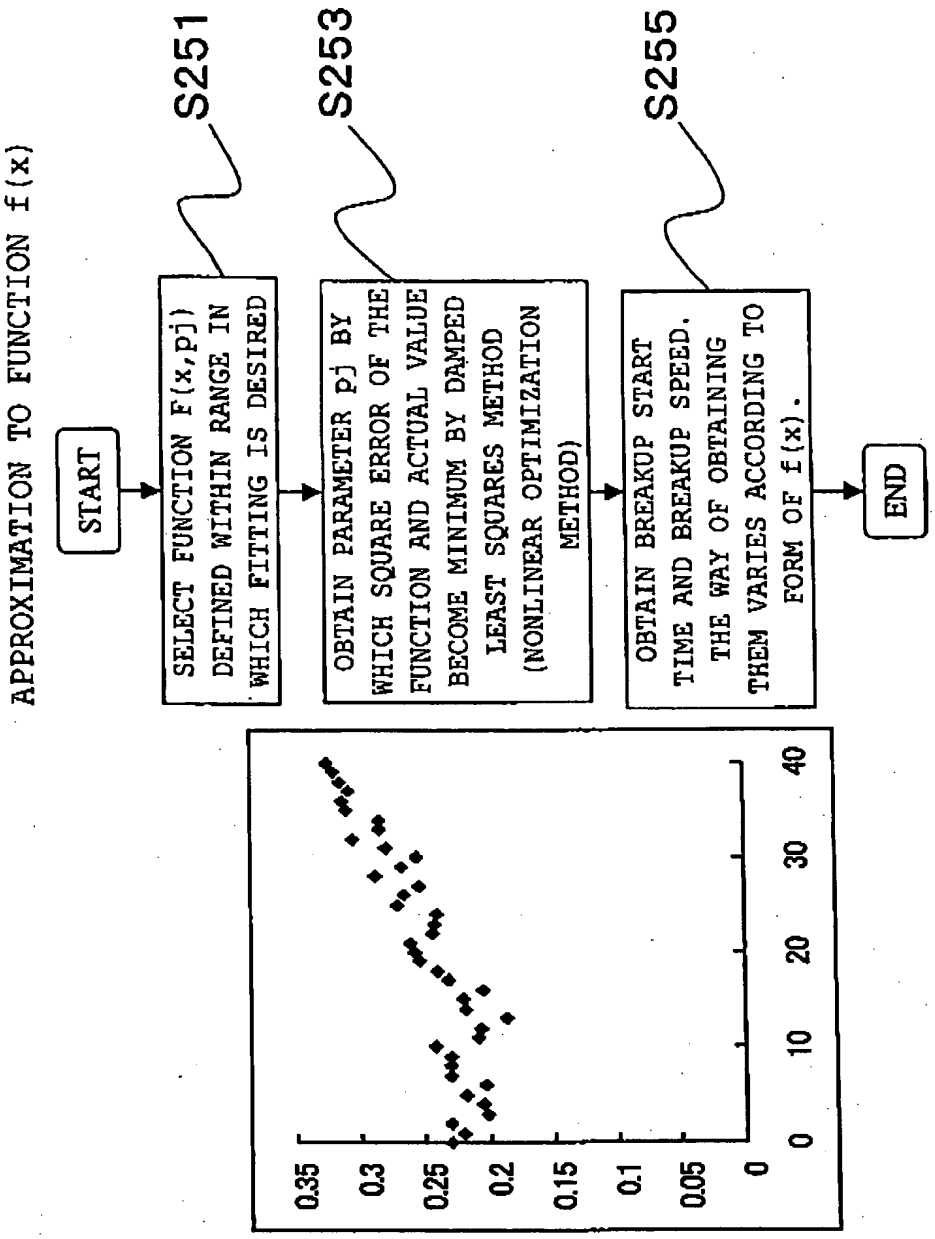
APPROXIMATION TO FUNCTION f(x)
START
S251
SELECT FUNCTION F(x,pj) DEFINED WITHIN RANGE IN WHICH FITTING IS DESIRED
S253
OBTAIN PARAMETER pj BY WHICH SQUARE ERROR OF THE FUNCTION AND ACTUAL VALUE BECOME MINIMUM BY DAMPED LEAST SQUARES METHOD (NONLINEAR OPTIMIZATION METHOD)
S255
OBTAIN BREAKUP START TIME AND BREAKUP SPEED. THE WAY OF OBTAINING THEM VARIES ACCORDING TO FORM OF f(x).
END
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
(a)
(b)

FIG. 6

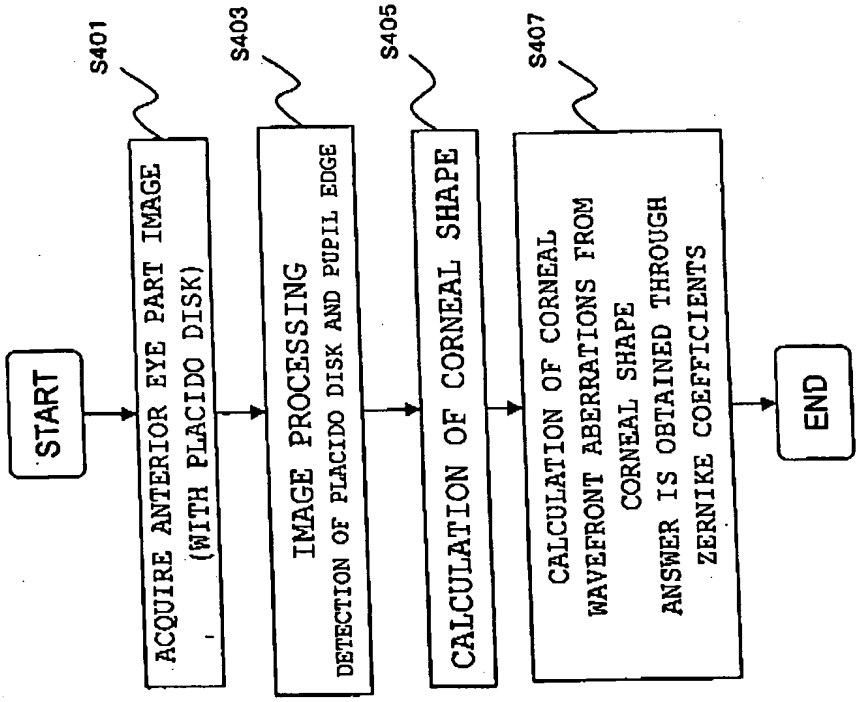
START
S401
ACQUIRE ANTERIOR EYE PART IMAGE (WITH PLACIDO DISK)
S403
IMAGE PROCESSING
DETECTION OF PLACIDO DISK AND PUPIL EDGE
S405
CALCULATION OF CORNEAL SHAPE
S407
CALCULATION OF CORNEAL WAVEFRONT ABERRATIONS FROM CORNEAL SHAPE
ANSWER IS OBTAINED THROUGH ZERNIKE COEFFICIENTS
END

FIG. 7

Title: OPHTHALMOLOGIC APPARATUS
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DOCKET NO.: 059277-0120

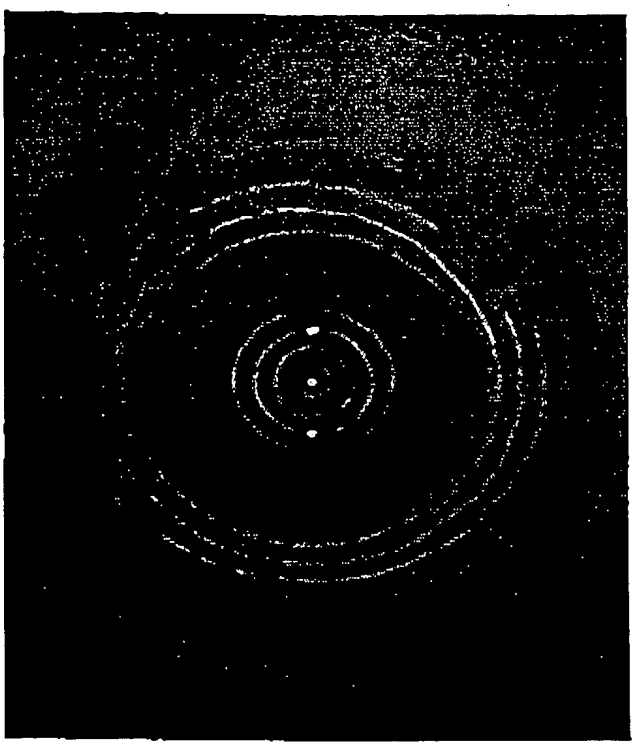


FIG. 8B

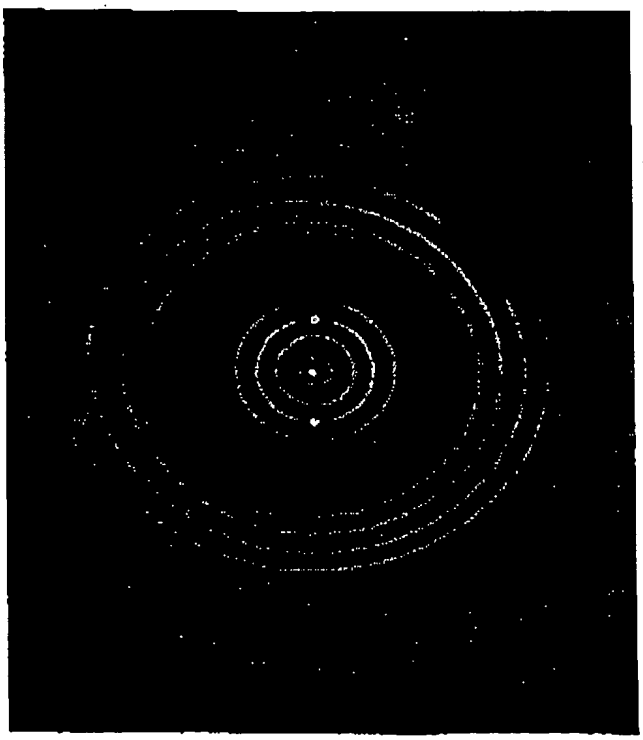


FIG. 8A

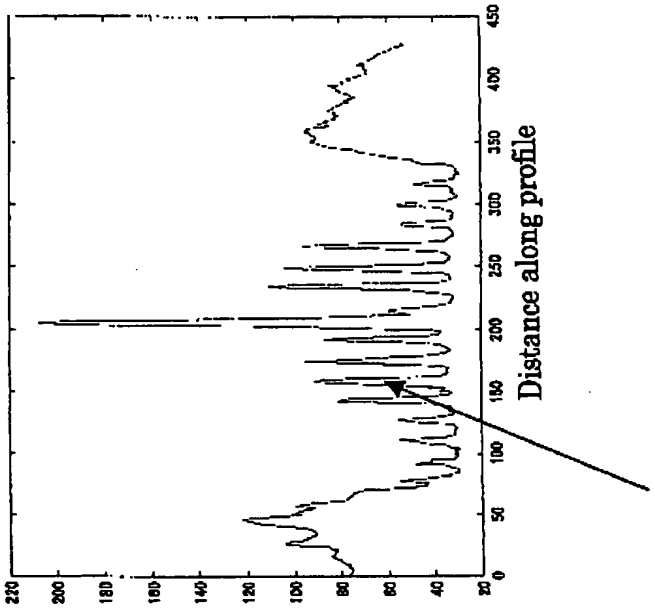


FIG. 9B

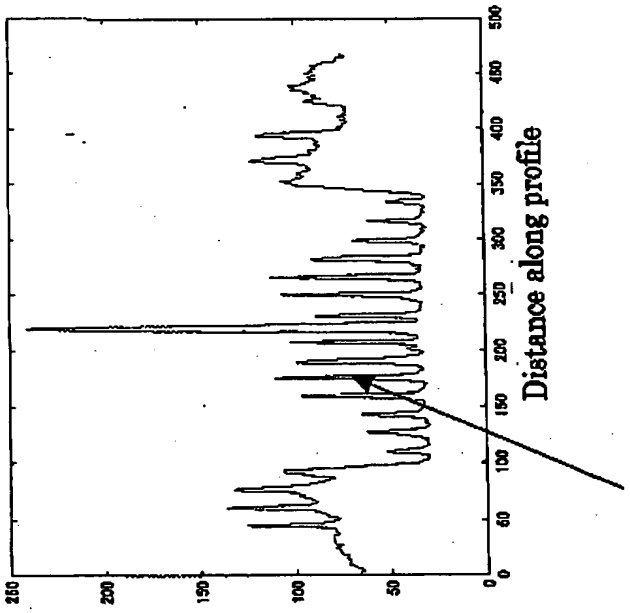


FIG. 9A

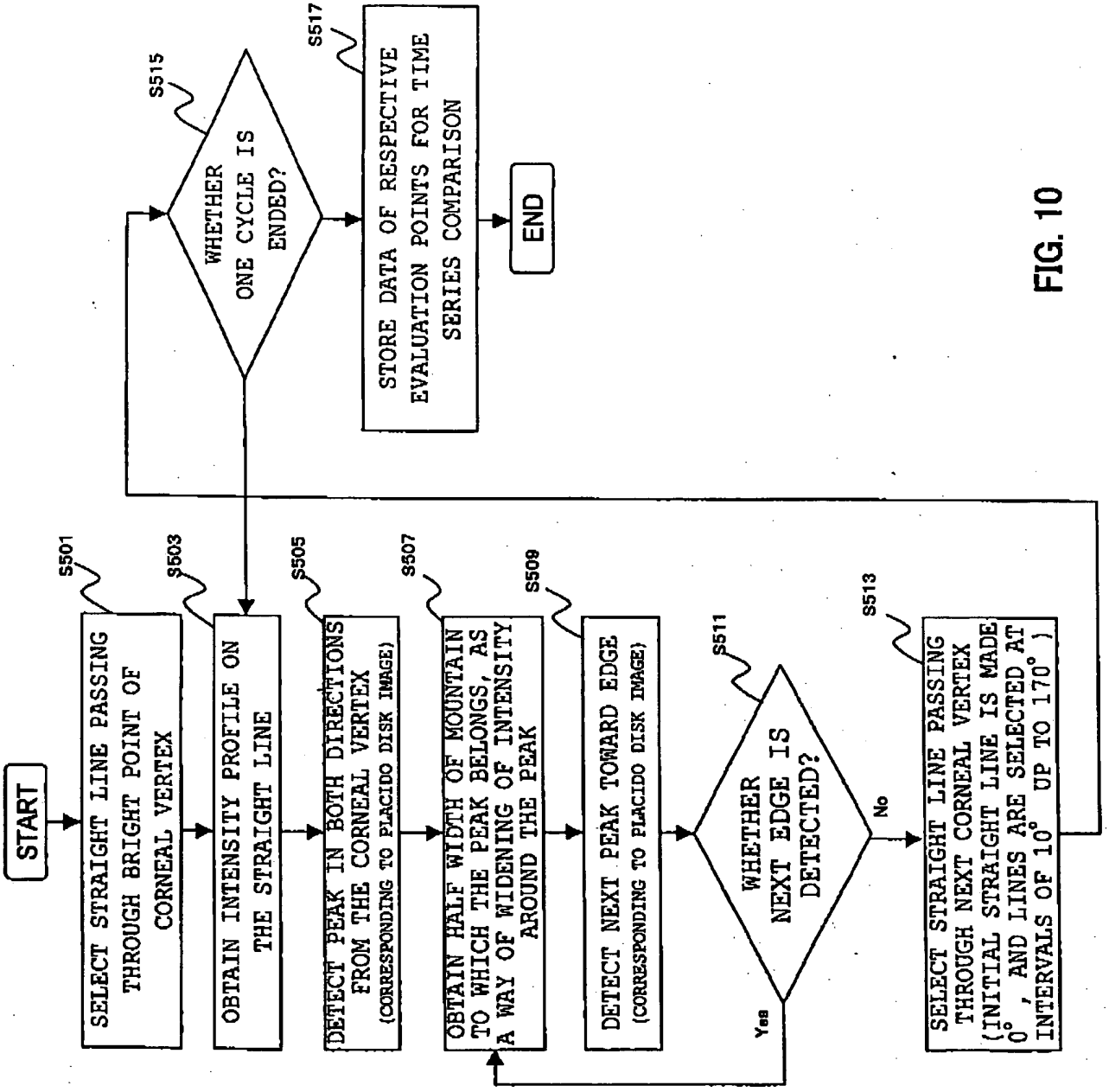

START
S501
SELECT STRAIGHT LINE PASSING THROUGH BRIGHT POINT OF CORNEAL VERTEX
S503
OBTAIN INTENSITY PROFILE ON THE STRAIGHT LINE
S505
DETECT PEAK IN BOTH DIRECTIONS FROM THE CORNEAL VERTEX (CORRESPONDING TO PLACIDO DISK IMAGE)
S507
OBTAIN HALF WIDTH OF MOUNTAIN TO WHICH THE PEAK BELONGS, AS A WAY OF WIDENING OF INTENSITY AROUND THE PEAK
S509
DETECT NEXT PEAK TOWARD EDGE (CORRESPONDING TO PLACIDO DISK IMAGE)
S511
WHETHER NEXT EDGE IS DETECTED?
Yes
No
S513
SELECT STRAIGHT LINE PASSING THROUGH NEXT CORNEAL VERTEX (INITIAL STRAIGHT LINE IS MADE 0°, AND LINES ARE SELECTED AT INTERVALS OF 10° UP TO 170°)
S515
WHETHER ONE CYCLE IS ENDED?
S517
STORE DATA OF RESPECTIVE EVALUATION POINTS FOR TIME SERIES COMPARISON
END

FIG. 10

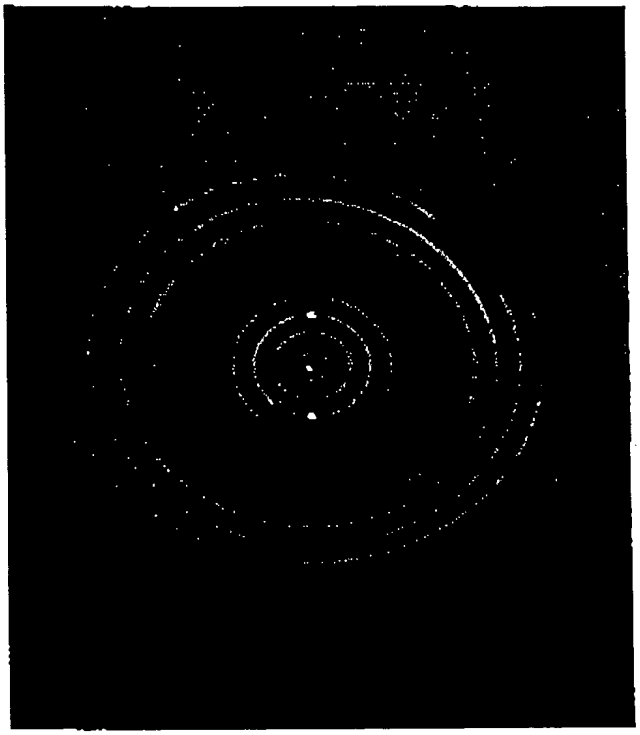


FIG. 11

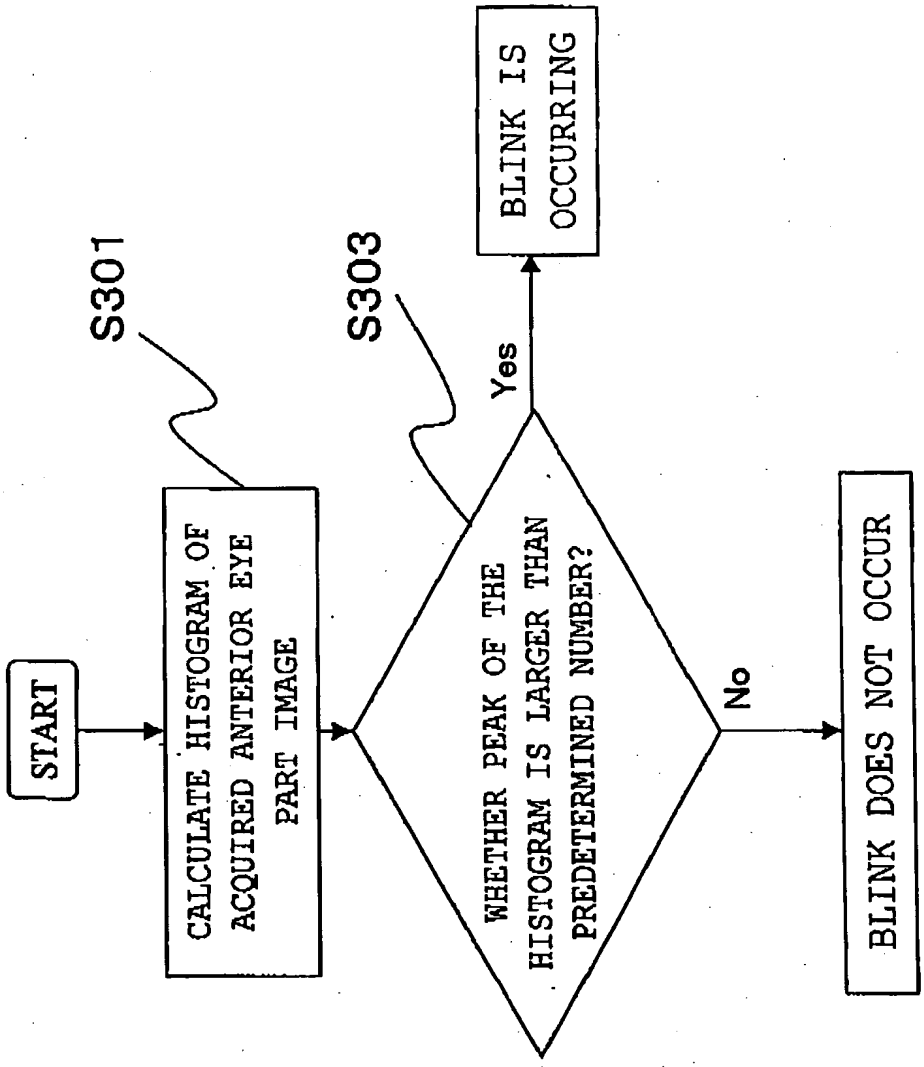

START
S301
CALCULATE HISTOGRAM OF ACQUIRED ANTERIOR EYE PART IMAGE
S303
WHETHER PEAK OF THE HISTOGRAM IS LARGER THAN PREDETERMINED NUMBER?
Yes
BLINK IS OCCURRING
No
BLINK DOES NOT OCCUR

FIG. 12

FIG. 13A

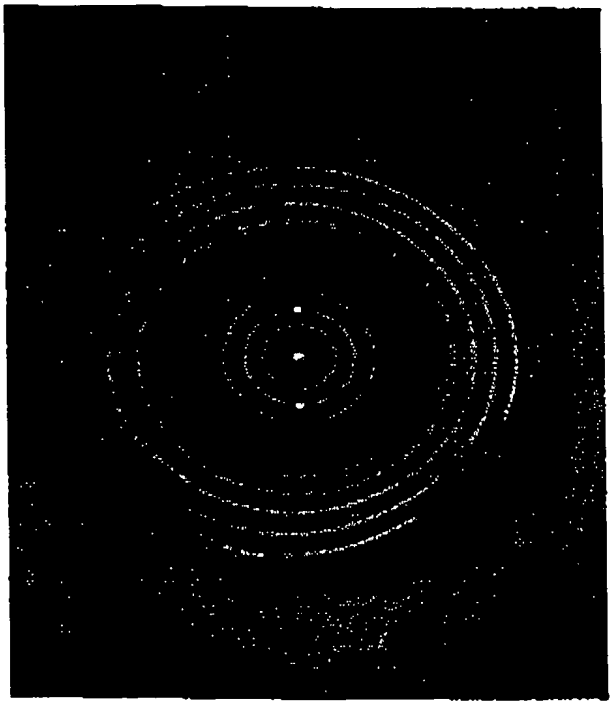
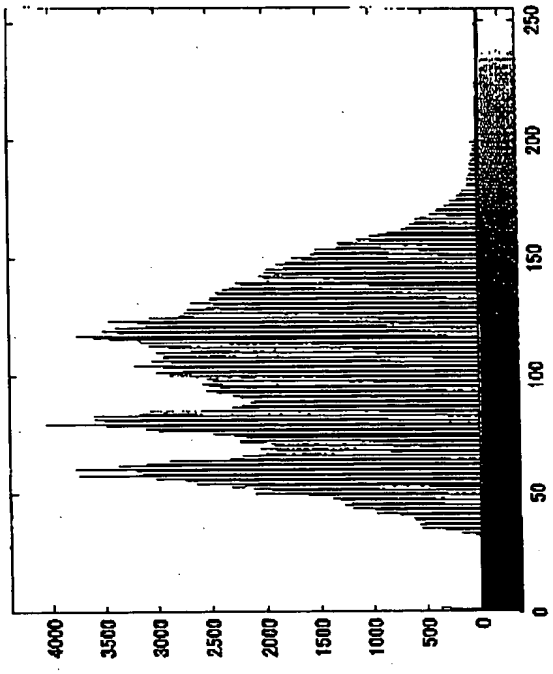


FIG. 13B



Title: OPHTHALMOLOGIC APPARATUS
Inventor(s): Toshifumi MIHASHI et al.
DOCKET NO.: 059277-0120

FIG. 14A

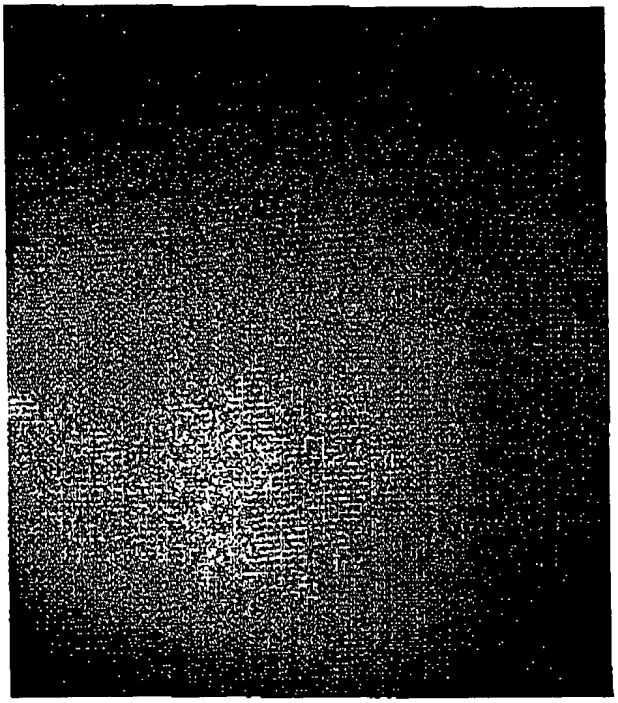
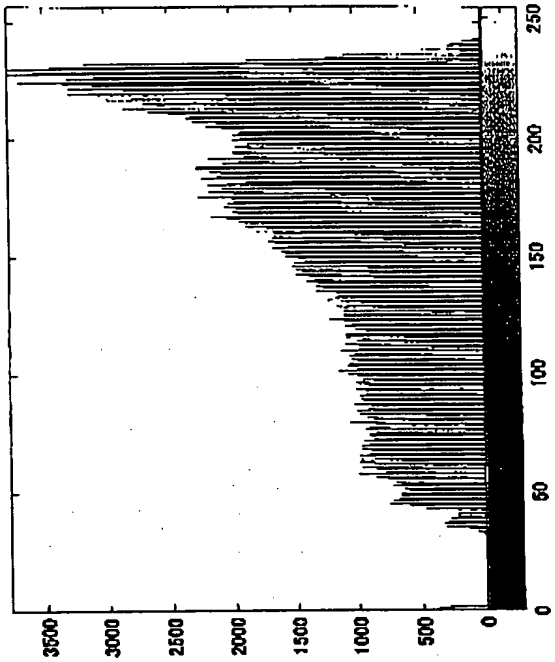


FIG. 14B



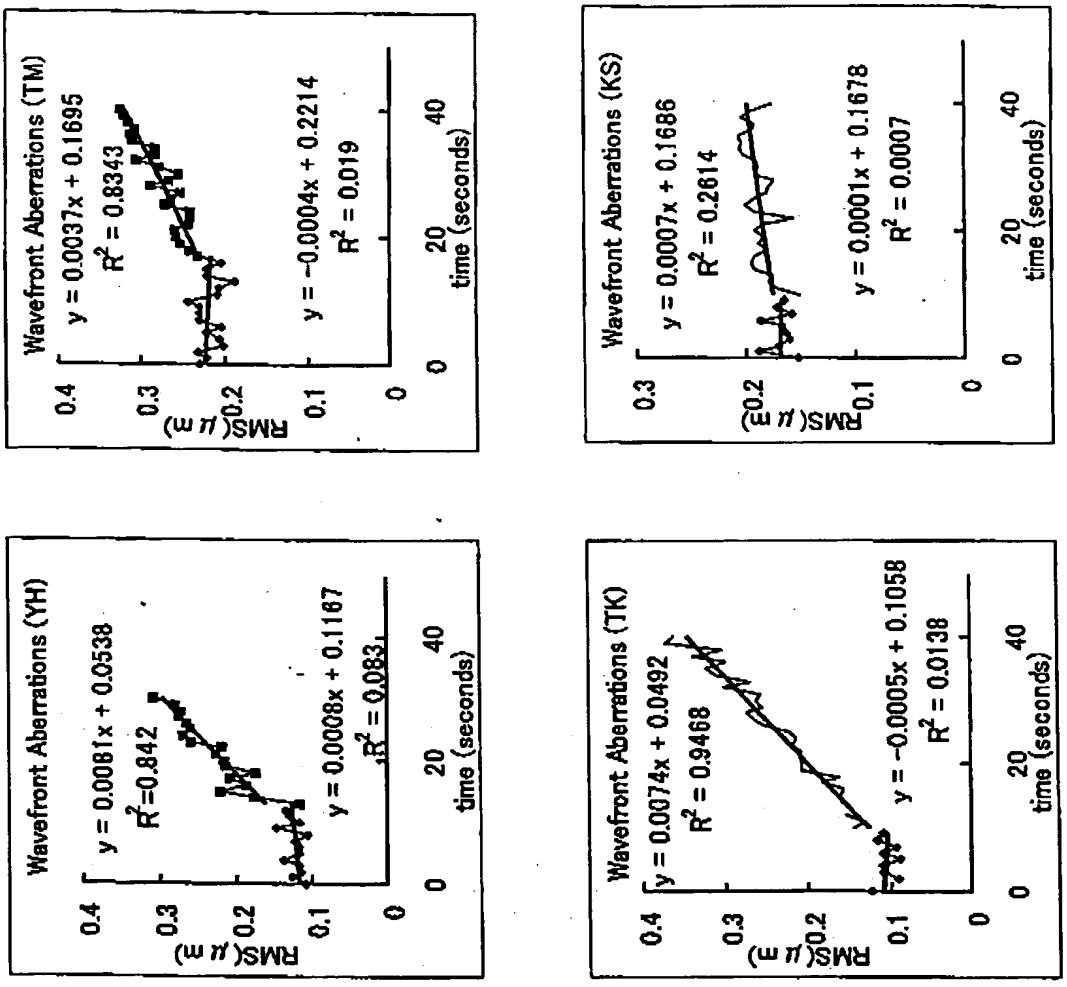

Wavefront Aberrations (TM)
y = 0.0037x + 0.1695
R² = 0.8343
y = -0.0004x + 0.2214
R² = 0.019
RMS(μm)
time (seconds)
Wavefront Aberrations (KS)
y = 0.0007x + 0.1686
R² = 0.2614
y = 0.0001x + 0.1678
R² = 0.0007
Wavefront Aberrations (YH)
y = 0.0081x + 0.0538
R²=0.842
y = 0.0008x + 0.1167
R² = 0.083
Wavefront Aberrations (TK)
y = 0.0074x + 0.0492
R² = 0.9468
y = -0.0005x + 0.1058
R² = 0.0138

FIG. 15

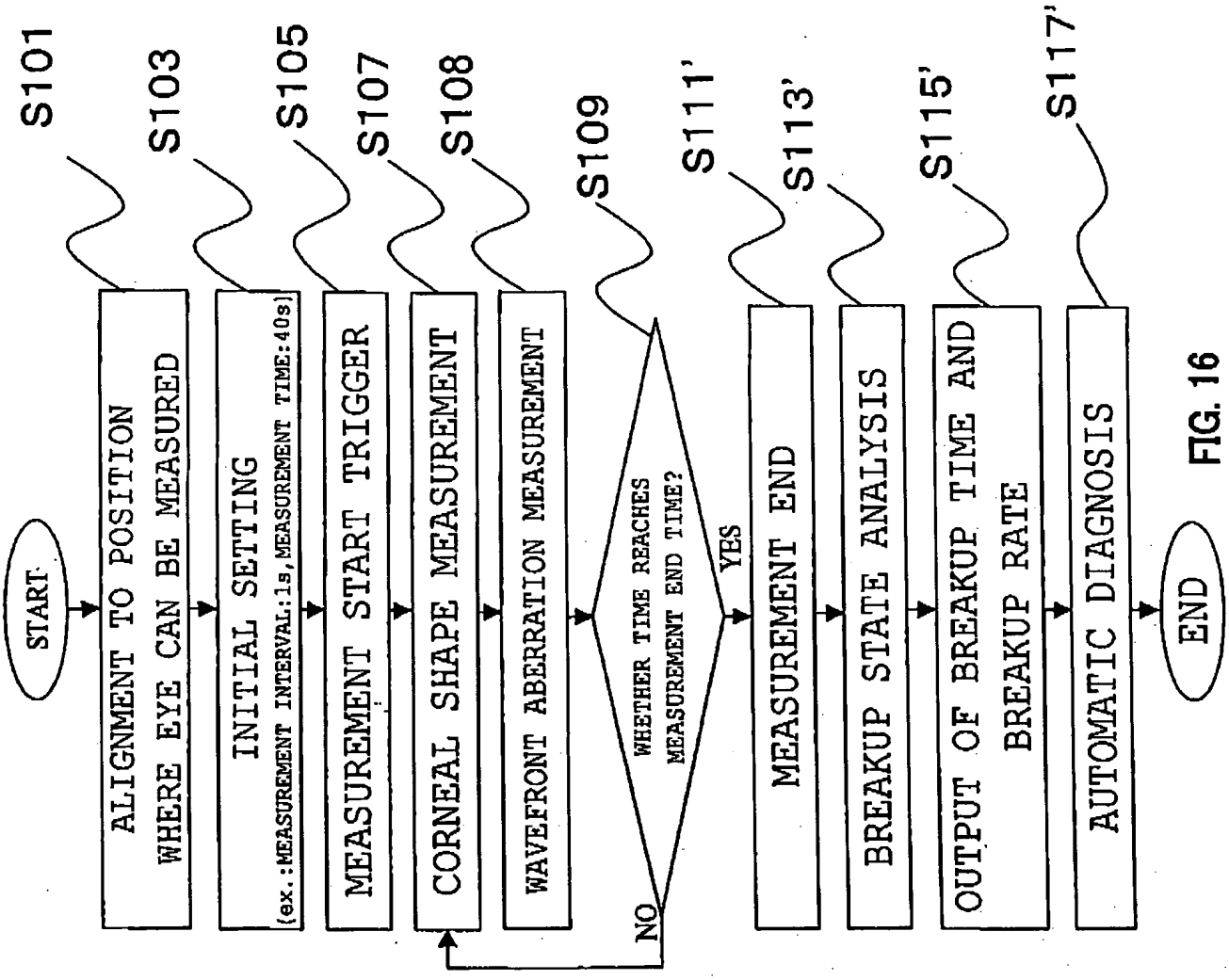

START
S101
ALIGNMENT TO POSITION WHERE EYE CAN BE MEASURED
S103
INITIAL SETTING
(ex.: MEASUREMENT INTERVAL: 1s, MEASUREMENT TIME: 40s)
S105
MEASUREMENT START TRIGGER
S107
CORNEAL SHAPE MEASUREMENT
S108
WAVEFRONT ABERRATION MEASUREMENT
S109
WHETHER TIME REACHES MEASUREMENT END TIME?
YES
NO
S111'
MEASUREMENT END
S113'
BREAKUP STATE ANALYSIS
S115'
OUTPUT OF BREAKUP TIME AND BREAKUP RATE
S117'
AUTOMATIC DIAGNOSIS
END

FIG. 16

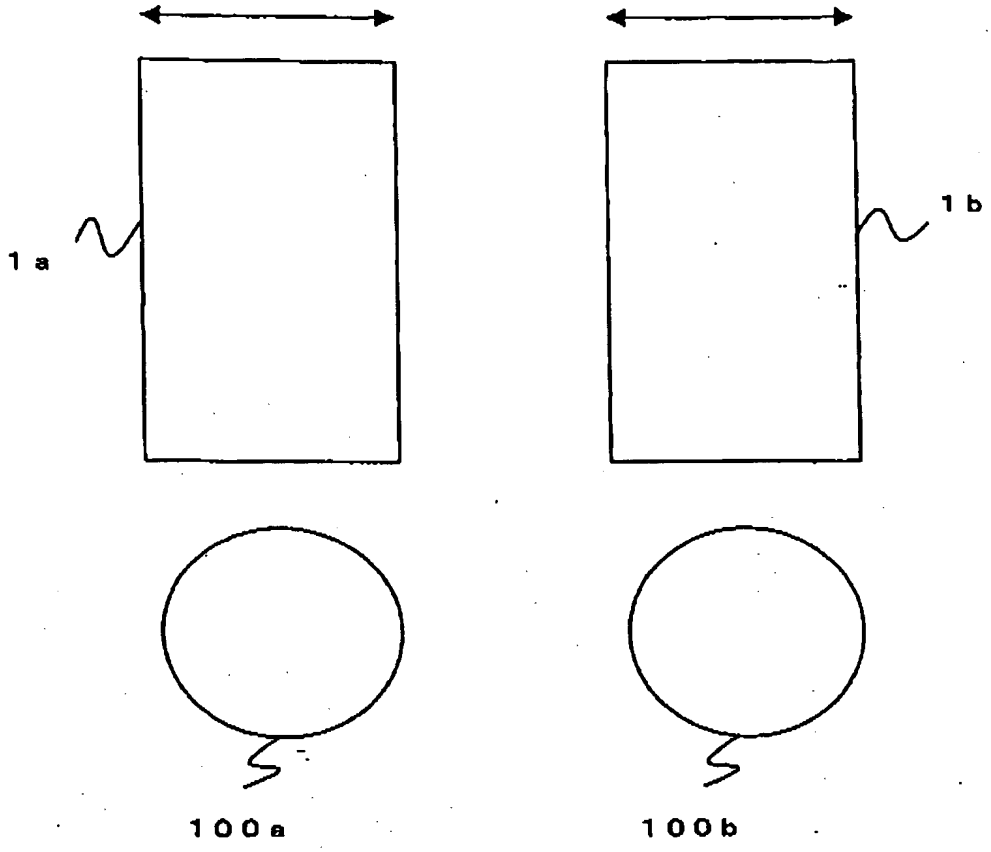


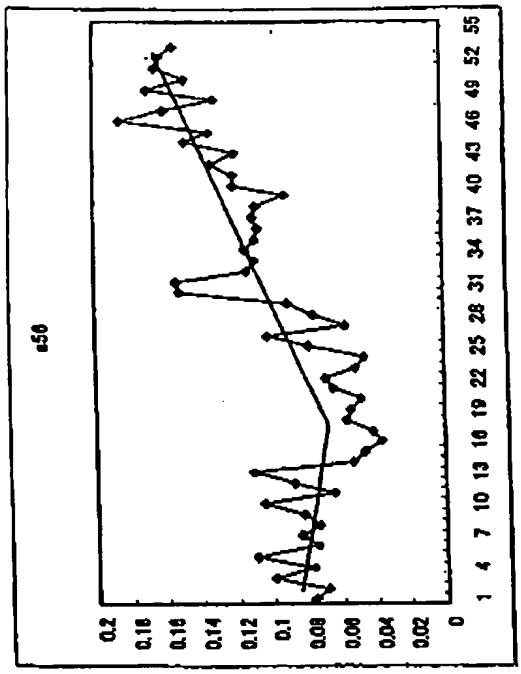
FIG. 17

i	2j - i	
0	0	1
1	-1	$r \sin(t)$
1	1	$\cos(t)\, r$
2	-2	$r^2 \sin(2t)$
2	0	$2r^2 - 1$
2	2	$r^2 \cos(2t)$
3	-3	$r^3 \sin(3t)$
3	-1	$(3r^3 - 2r)\sin(t)$
3	1	$(3r^3 - 2r)\cos(t)$
3	3	$r^3 \cos(3t)$
4	-4	$r^4 \sin(4t)$
4	-2	$(4r^4 - 3r^2)\sin(2t)$
4	0	$6r^4 - 6r^2 + 1$
4	2	$(4r^4 - 3r^2)\cos(2t)$
4	4	$r^4 \cos(4t)$
5	-5	$r^5 \sin(5t)$
5	-3	$(5r^5 - 4r^3)\sin(3t)$
5	-1	$(10r^5 - 12r^3 + 3r)\sin(t)$
5	1	$(10r^5 - 12r^3 + 3r)\cos(t)$
5	3	$(5r^5 - 4r^3)\cos(3t)$
5	5	$r^5 \cos(5t)$
6	-6	$r^6 \sin(6t)$
6	-4	$(6r^6 - 5r^4)\sin(4t)$
6	-2	$(15r^6 - 20r^4 + 6r^2)\sin(2t)$
6	0	$20r^6 - 30r^4 + 12r^2 - 1$
6	2	$(15r^6 - 20r^4 + 6r^2)\cos(2t)$
6	4	$(6r^6 - 5r^4)\cos(4t)$
6	6	$r^6 \cos(6t)$

FIG. 18

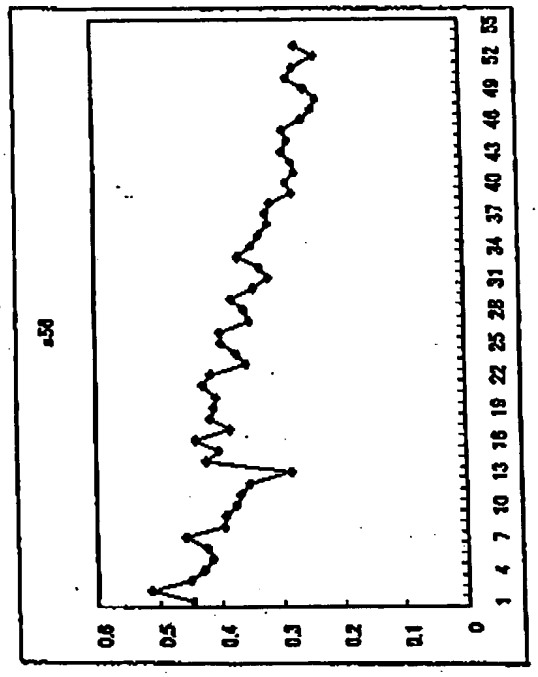
i	2j - i	
0	0	1
1	-1	y
1	1	x
2	-2	$2yx$
2	0	$2x^2+2y^2-1$
2	2	x^2-y^2
3	-3	$3yx^2-y^3$
3	-1	$3yx^2+3y^3-2y$
3	1	$3x^3+3xy^2-2x$
3	3	x^3-3xy^2
4	-4	$4yx^3-4y^3x$
4	-2	$8yx^3+8y^3x-6yx$
4	0	$6x^4+12x^2y^2+6y^4-6x^2-6y^2+1$
4	2	$4x^4-4y^4-3x^2+3y^2$
4	4	$x^4-6x^2y^2+y^4$
5	-5	$5yx^4-10y^3x^2+y^5$
5	-3	$15yx^4+10y^3x^2-5y^5-12yx^2+4y^3$
5	-1	$10yx^4+20y^3x^2+10y^5-12yx^2-12y^3+3y$
5	1	$10x^5+20x^3y^2+10xy^4-12x^3-12xy^2+3x$
5	3	$5x^5-10x^3y^2-15xy^4-4x^3+12xy^2$
5	5	$x^5-10x^3y^2+5xy^4$
6	-6	$6yx^5-20y^3x^3+6y^5x$
6	-4	$24yx^5-24y^5x-20yx^3+20y^3x$
6	-2	$30yx^5+60y^3x^3+30y^5x-40yx^3-40y^3x+12yx$
6	0	$20x^6+60x^4y^2+60x^2y^4+20y^6-30x^4-60x^2y^2-30y^4+12x^2+12y^2-1$
6	2	$15x^6+15x^4y^2-15x^2y^4-15y^6-20x^4+20y^4+6x^2-6y^2$
6	4	$6x^6-30x^4y^2-30x^2y^4+6y^6-5x^4+30x^2y^2-5y^4$
6	6	$x^6-15x^4y^2+15x^2y^4-y^6$

FIG. 19



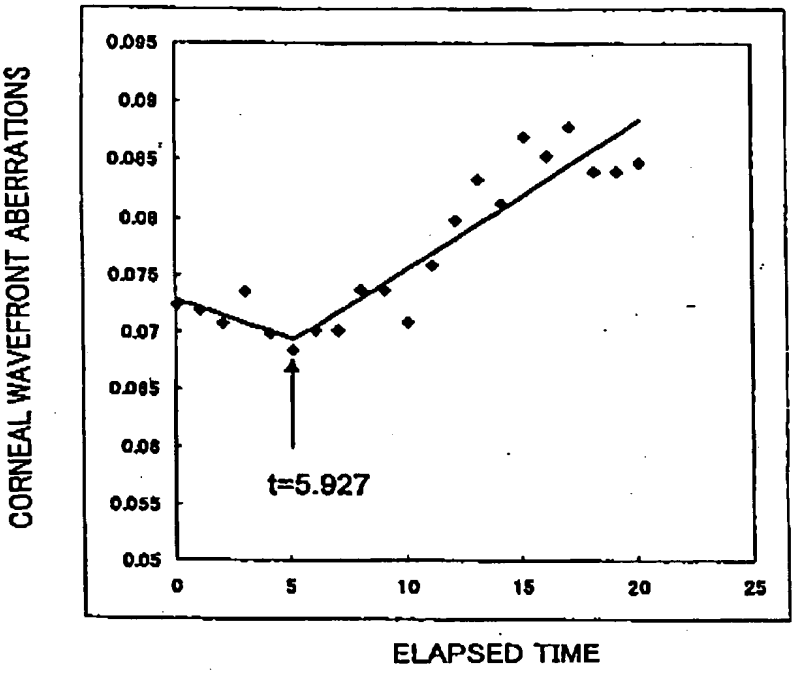
FIFTH AND SIXTH ABERRATIONS

FIG. 20B



THIRD AND FOURTH ABERRATIONS

FIG. 20A



$$\text{CORNEAL WAVEFRONT ABERRATION} = \begin{cases} -0.00418\,(t-5.927)+0.09299, & \text{for } t<5.927, \\ 0.00458\,(t-5.927)+0.09299, & \text{for } t\geq 5.927. \end{cases}$$

FIG. 21

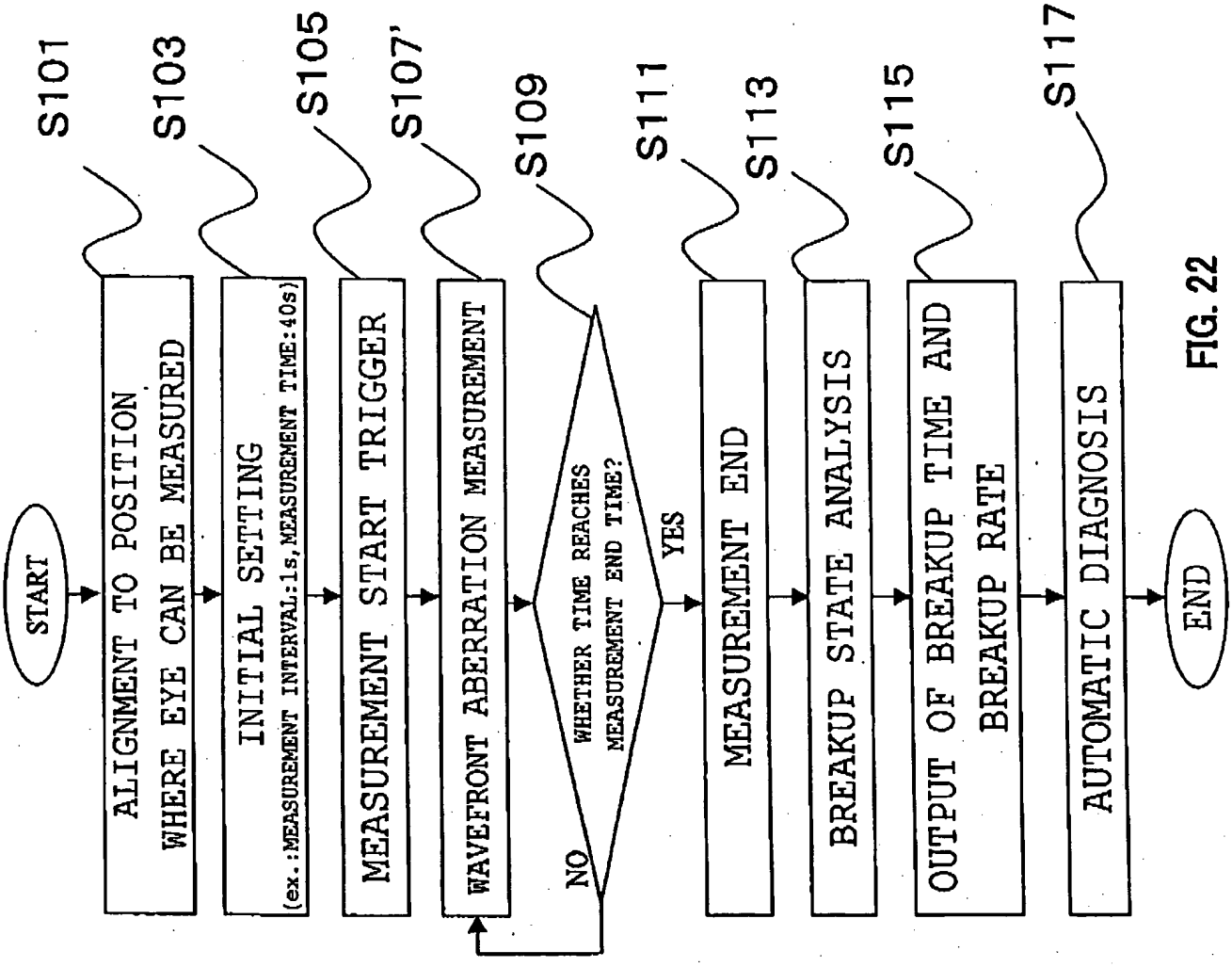

START
S101
ALIGNMENT TO POSITION WHERE EYE CAN BE MEASURED
S103
INITIAL SETTING
(ex.:MEASUREMENT INTERVAL:1s,MEASUREMENT TIME:40s)
S105
MEASUREMENT START TRIGGER
S107'
WAVEFRONT ABERRATION MEASUREMENT
S109
WHETHER TIME REACHES MEASUREMENT END TIME?
NO
YES
S111
MEASUREMENT END
S113
BREAKUP STATE ANALYSIS
S115
OUTPUT OF BREAKUP TIME AND BREAKUP RATE
S117
AUTOMATIC DIAGNOSIS
END

FIG. 22